An Introduction to Remote Sensing

Using Satellites for Improved Flood Monitoring and Prediction

World Bank, Washington DC

March 7th, 2013

ARSET

Applied Remote SEnsing Training

A project of NASA Applied Sciences

Applied Remote Sensing Training Program (ARSET)

Objectives

•Provide end-users with **professional technical workshops**

•Build long term partnerships with communities and institutions in the public and private sectors.

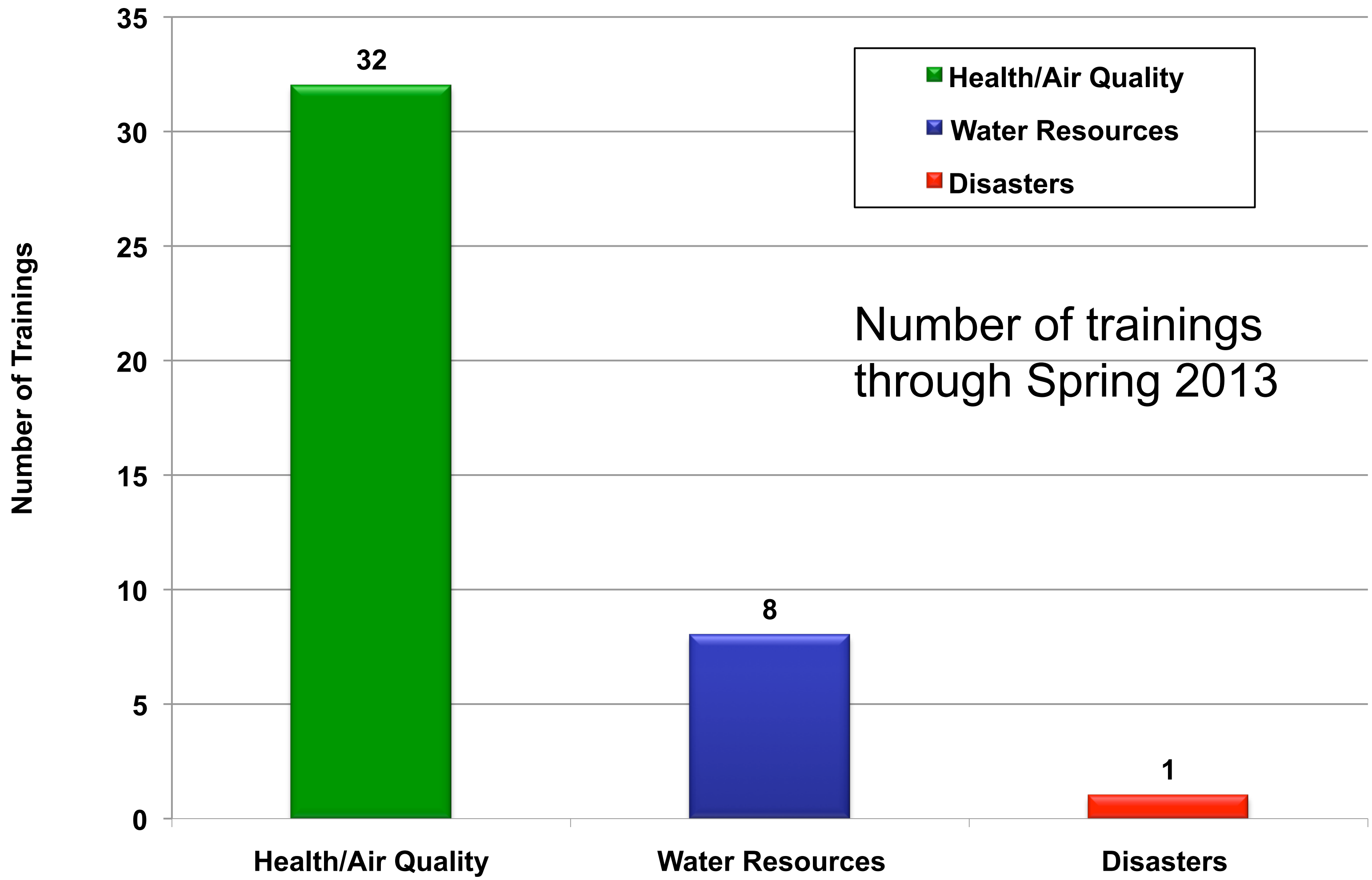
Online and hands-on courses:

- **Who:** policy makers, environmental managers, modelers and other professionals in the public and private sectors.

  Where: U.S and internationally
- **When**: throughout the year. Check websites.
- Do NOT require prior remote- sensing background.
- Presentations and hands-on guided computer exercises on how to access, interpret and use NASA satellite images for decision-support.

NASA Training for California Air Resources Board, Sacramento, CA December 2011

Number of ARSET Trainings



Gradual Learning Approach

Basic in person course

- For individuals and institutions new to remote sensing
- Trainings at professional conferences

Basic online courses

- Provide background material in for in person trainings

Advanced in person or online courses

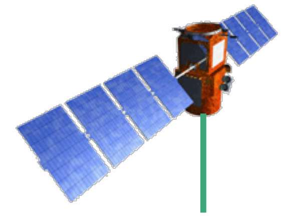
- Focused on a specific application/problem: for example monitoring fire and smoke in the western US (summer 2012).
- Requires basic online or in person course.

Online courses are free – contact us if interested in a hands-on course

Outline

- What is Satellite Remote Sensing ?
- Satellite orbits
- Spatial and Temporal Resolutions
- Data Processing and Levels
- Data formats

Why use Remote Sensing to Study the Earth ?



- Provides visual Global information

- Complements ground-monitoring networks or provides information where there are no ground-based measurements

- Provides advance warning of impending environmental events and disasters.

How Do Satellites Make Measurements?

- Passive satellite sensors measure radiation reflected or emitted by the earth-atmosphere system
  - Radiance

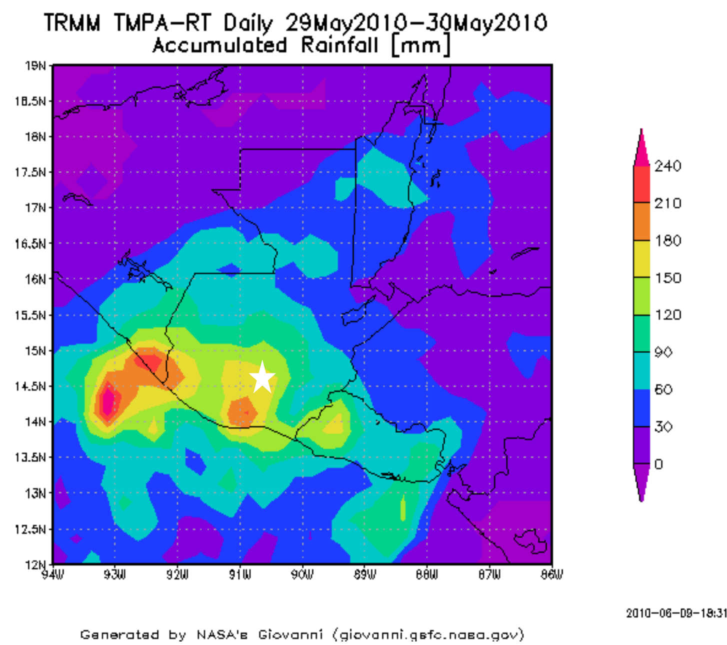
- Radiance is converted to a geophysical parameter.

Examples:

Accumulated Rainfall

Snow Cover

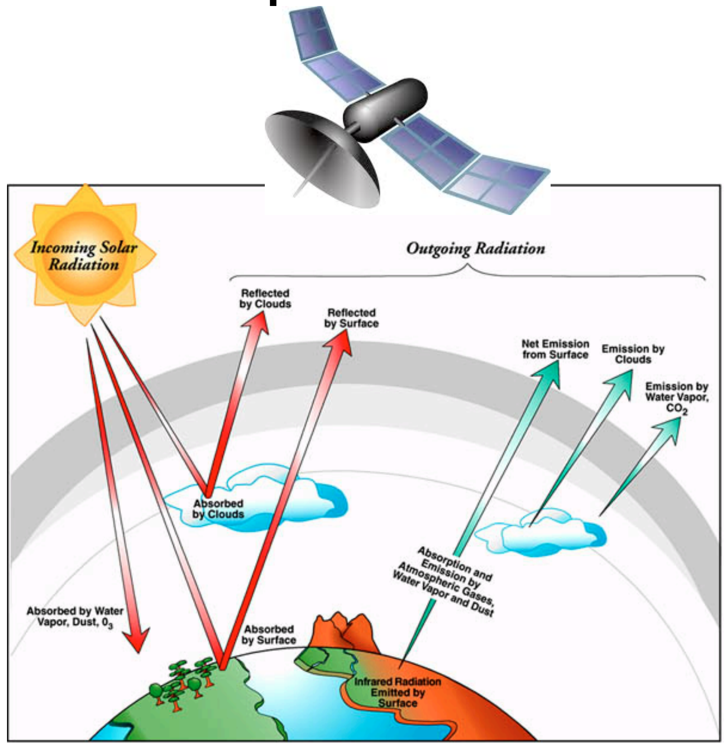
Accumulated Rainfall
Guatemala



Satellite Remote Sensing: measuring properties of earth-atmosphere system from space

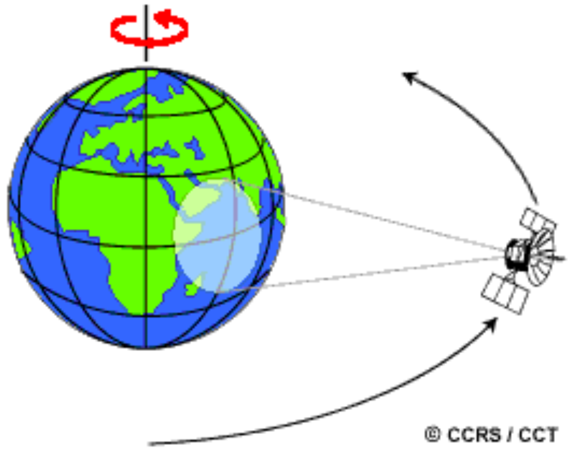
- The intensity of reflected and emitted radiation to space at is influenced by the surface and atmospheric conditions

- **Thus, satellite measurements contain information about surface and atmospheric conditions**



Types of satellite orbits

Geostationary orbit



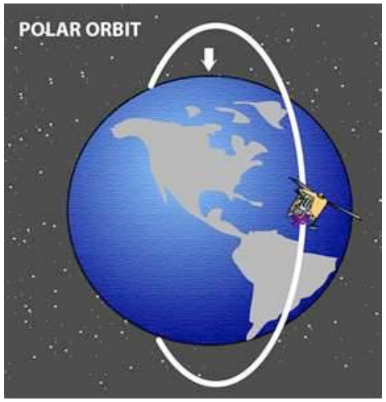
Fixed' above earth at ~36,000 km

Frequent Measurements

Limited Spatial Coverage

Low Earth Orbit (LEO)

Polar (Aqua, Terra)

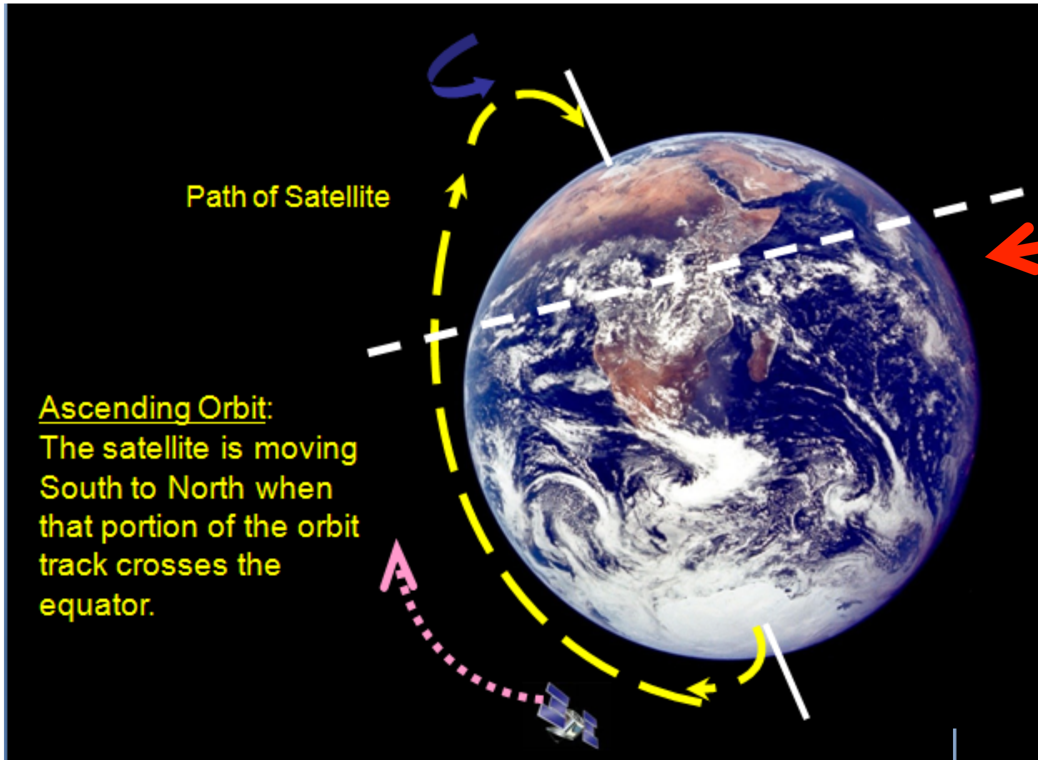


Nonpolar (TRMM)

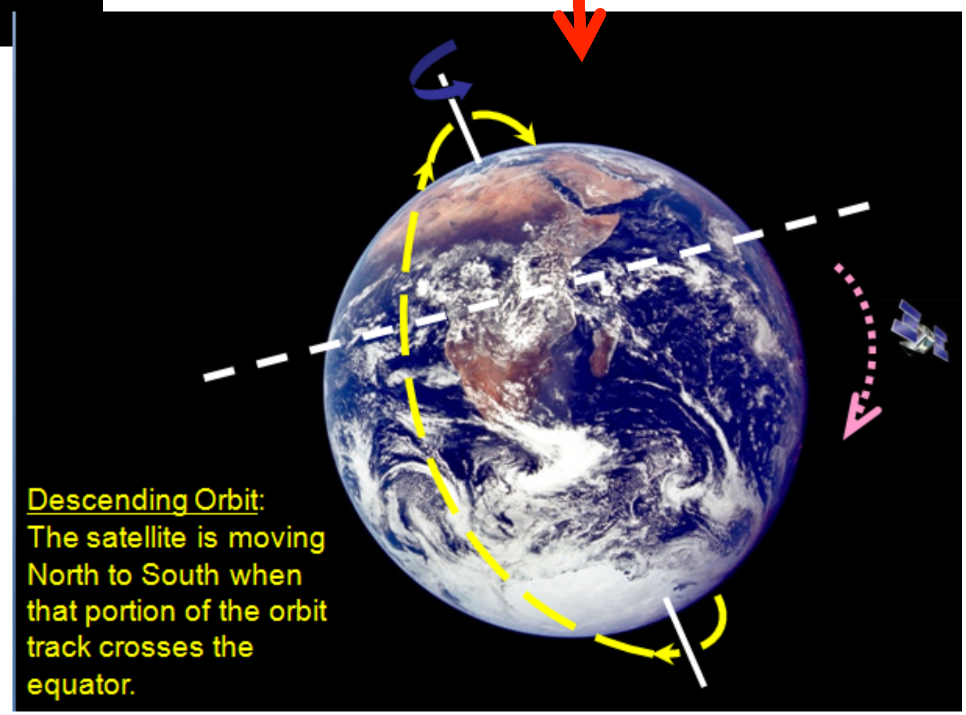
Circular orbit constantly moving relative to the Earth at 160-2000 km

Less Frequent measurements (< 2 times per day)

Large (global) spatial Coverage

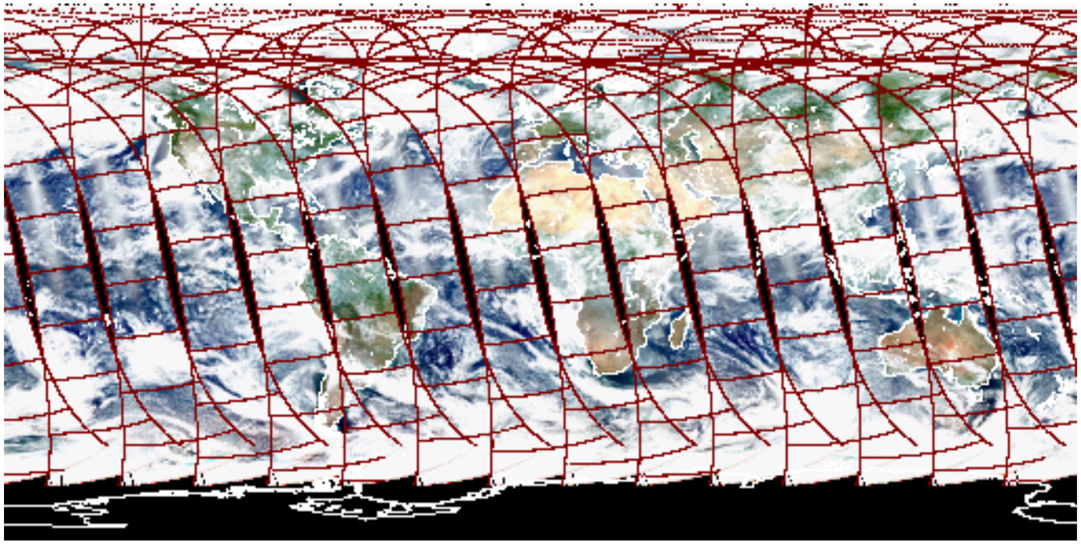


Ascending
vs
Descending



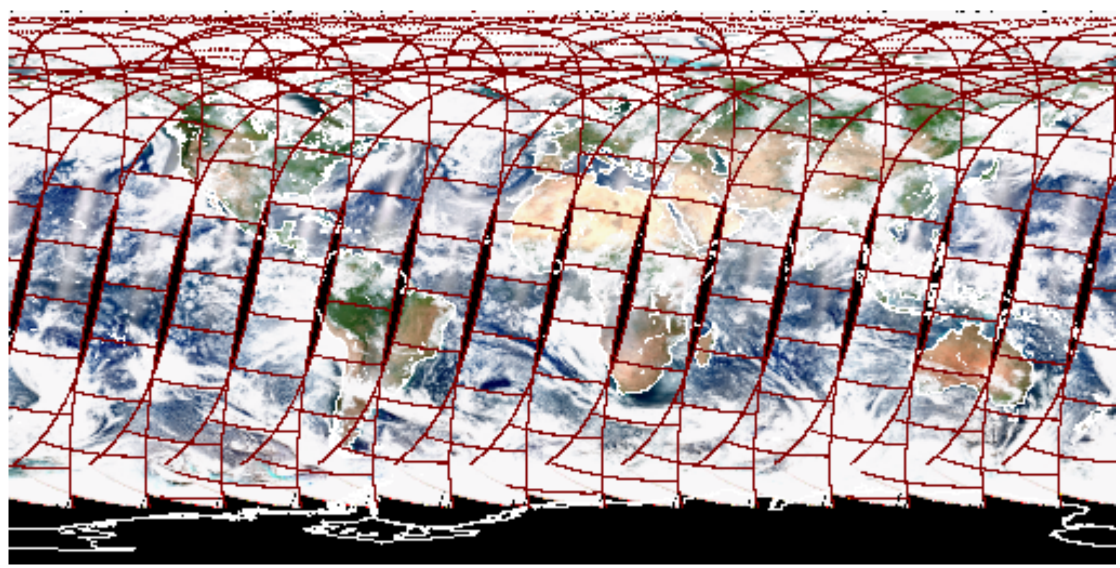
Polar Orbits

Aqua (“ascending” orbit) day time



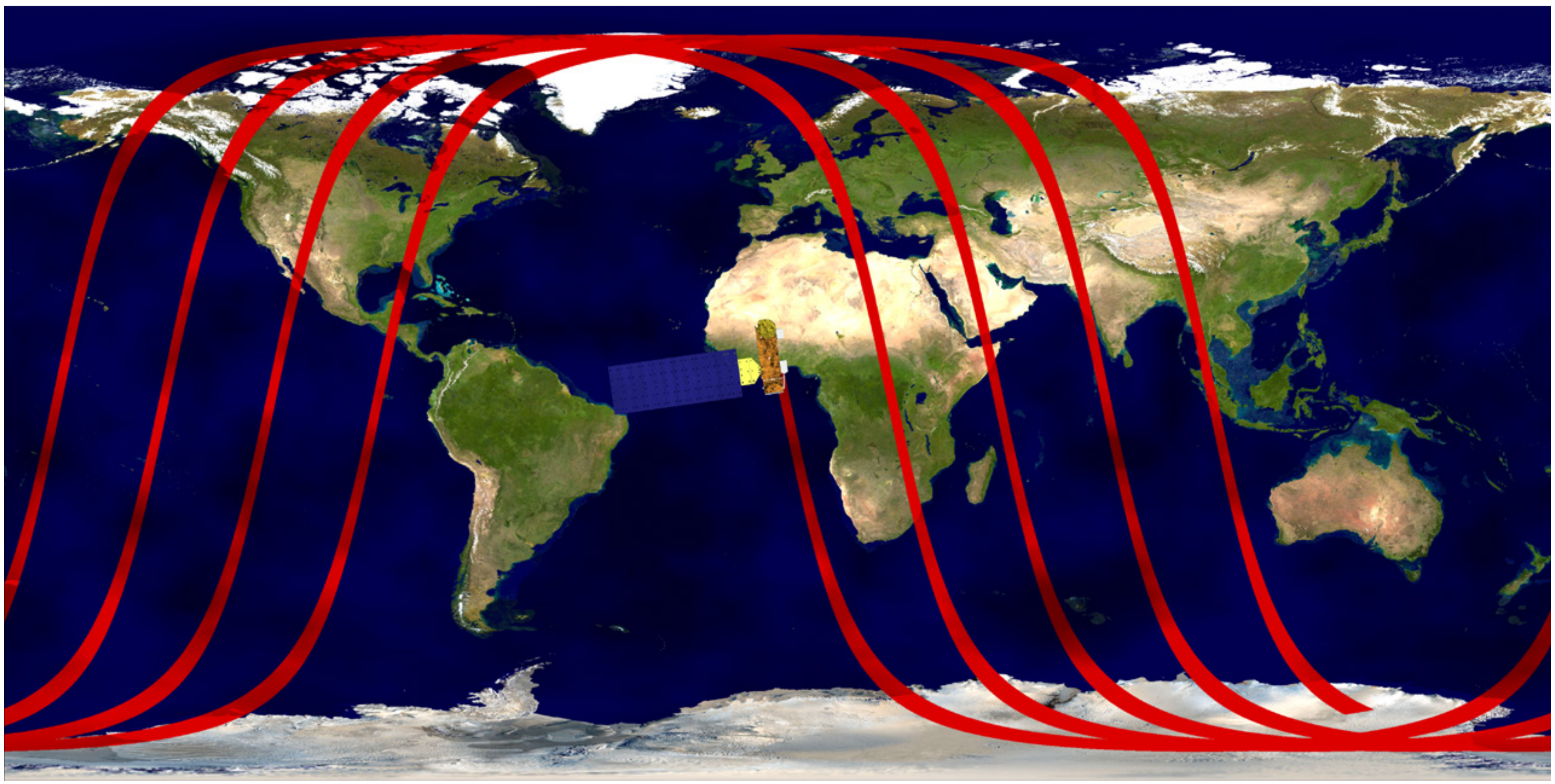
LEO Polar Orbiting

Terra (“descending”) Day time



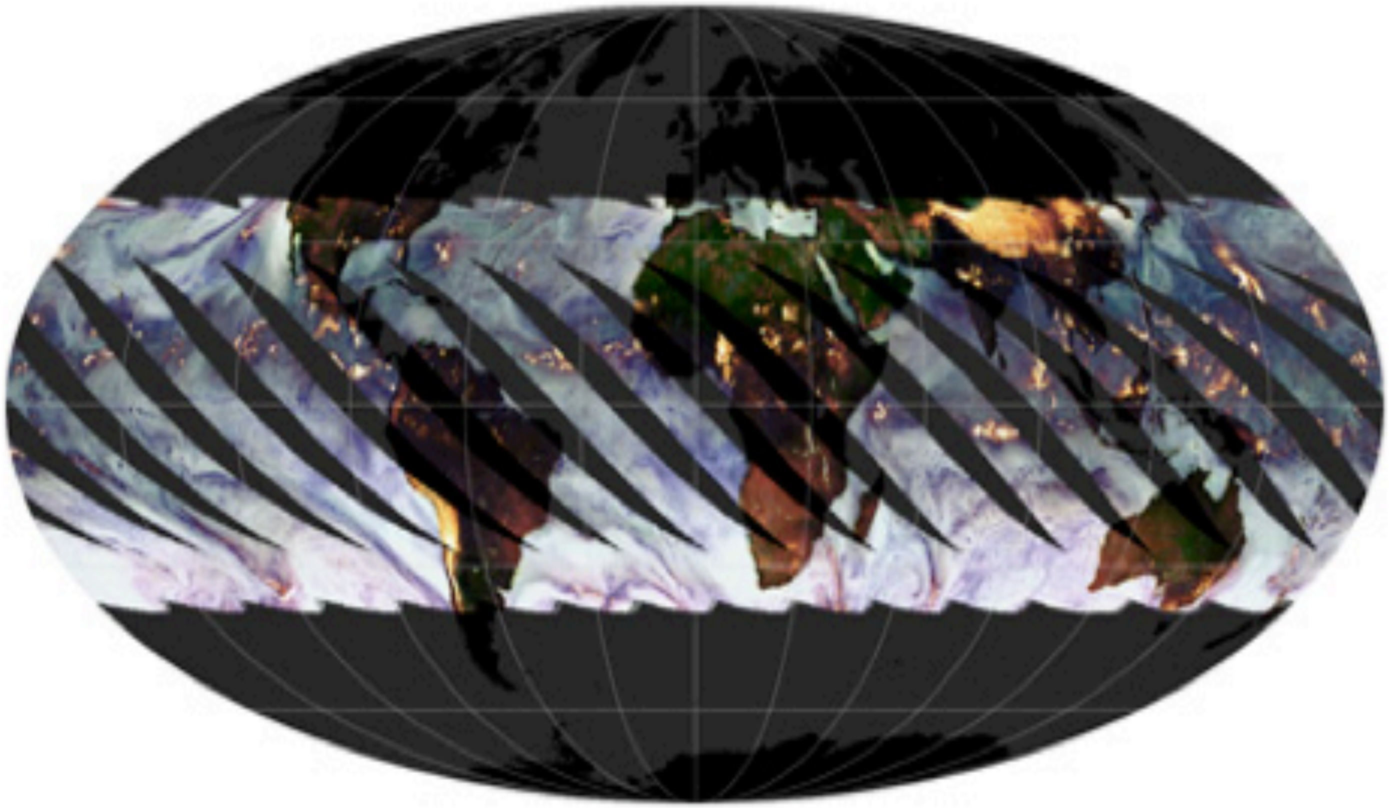
Aqua's Orbit

- Near-polar, sun-synchronous, orbiting the Earth every 98.8 minutes, crossing the equator going north (daytime ascending) at 1:30 p.m. and going south (night time descending) at 1:30 a.m.
- The orbit track changes every day but will repeat on a 16 day cycle. **This is true for Aqua, Terra, and TRMM.**



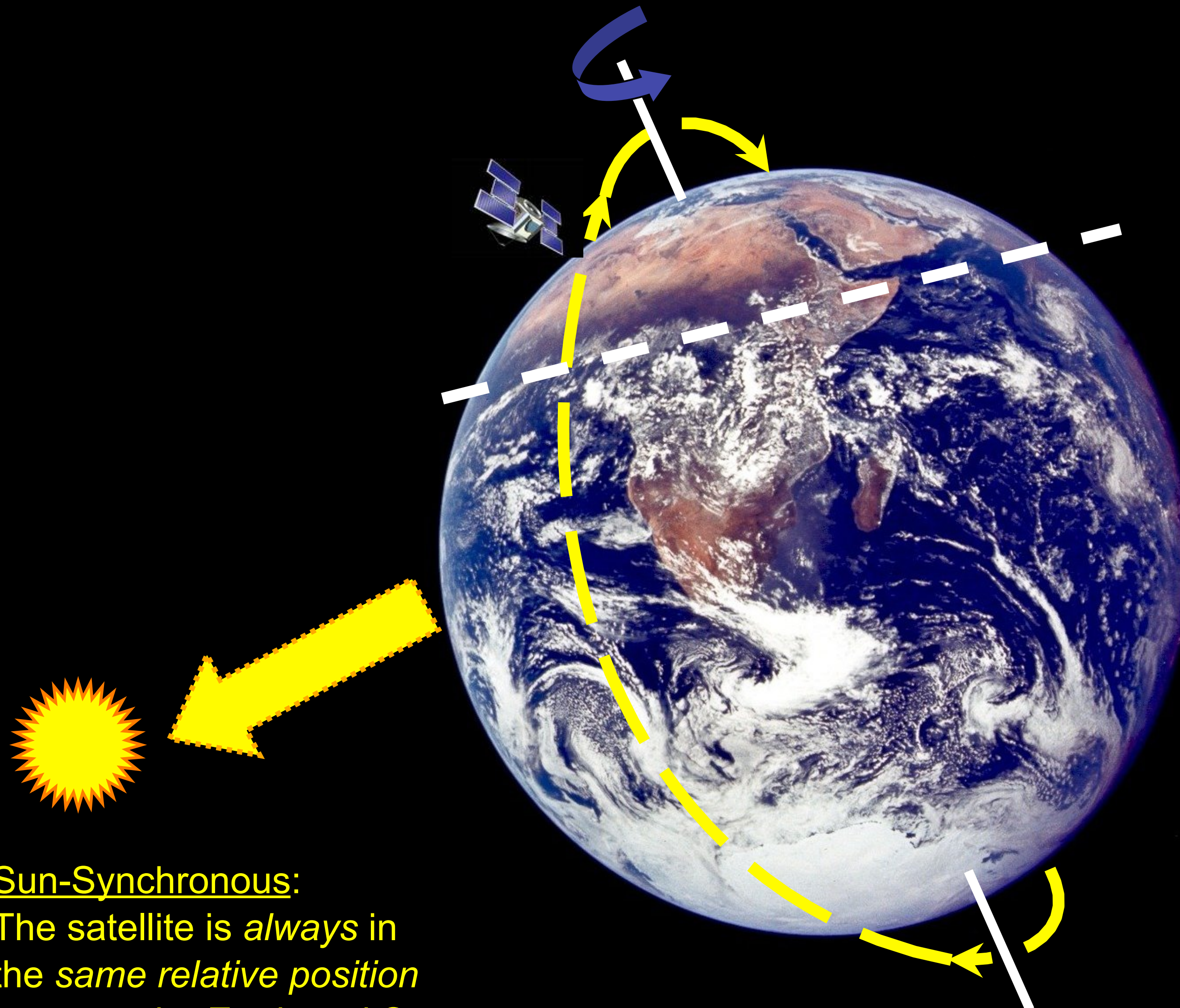
LEO nonpolar Orbiting

TRMM (“ascending” orbit)



TRMM’s Low orbit allows its instruments to concentrate on the tropics. This image shows half the observations TRMM makes in a single day

Earth-Observing Satellites



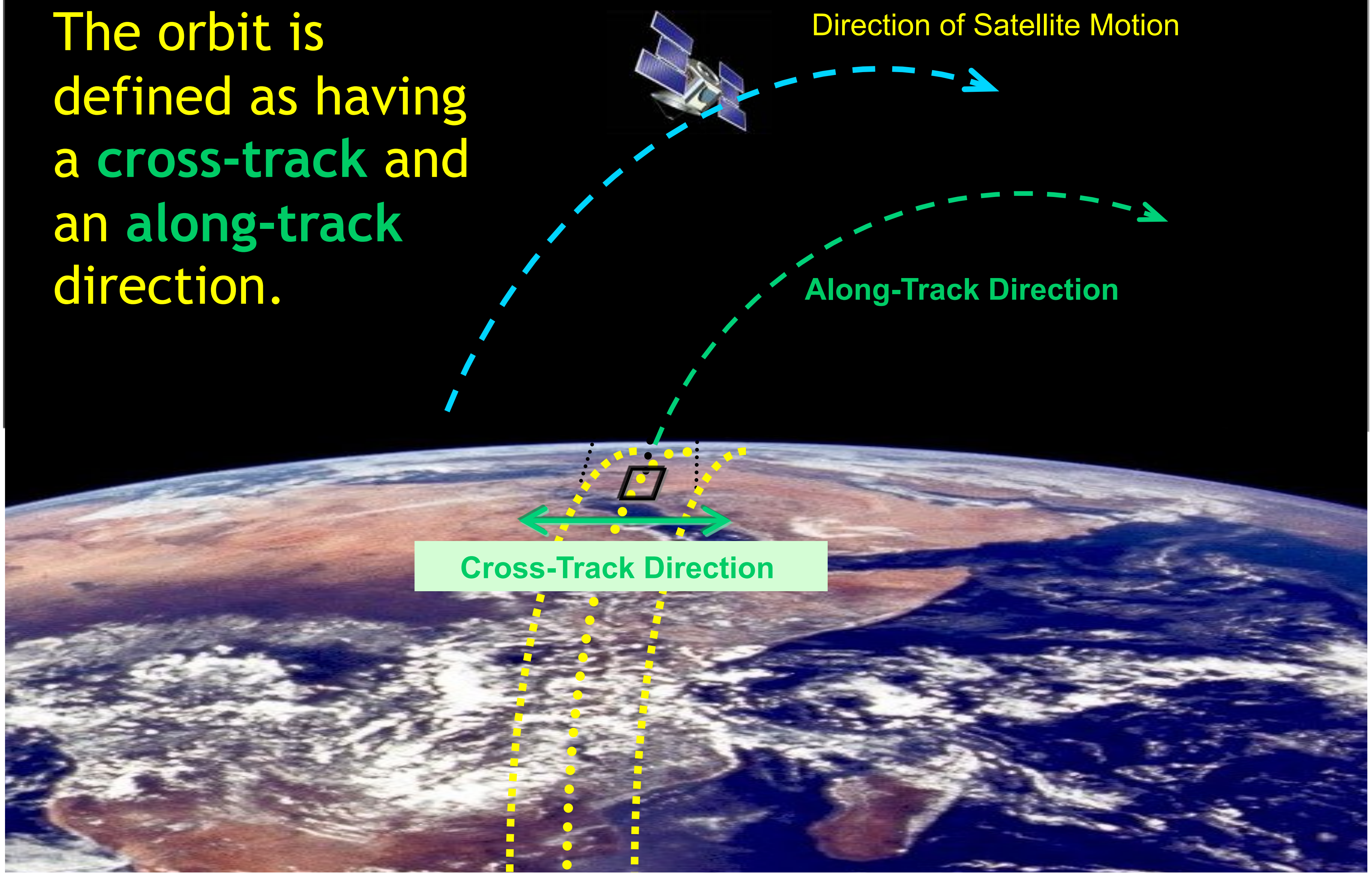
<u>Equator-Crossing Time</u>:
The local apparent solar time when the satellite crosses the equator.

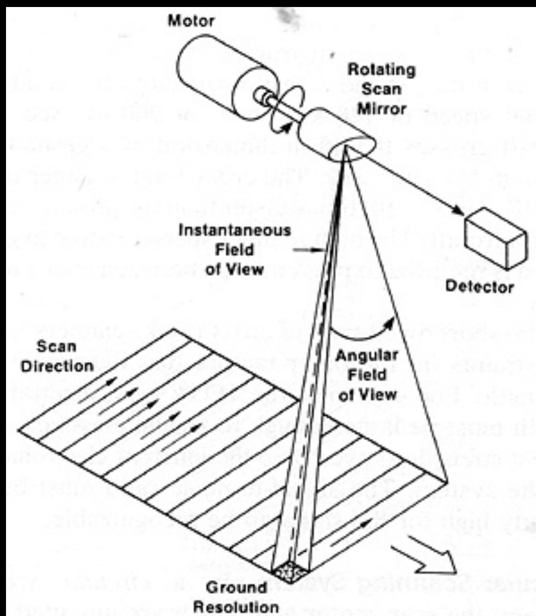
Example: Terra has an equatorial crossing time of 10:30 am, and is called an "AM" or morning satellite.

<u>Sun-Synchronous</u>:
The satellite is *always* in the *same relative position* between the Earth and Sun

Field-of-View (FOV)

The orbit is defined as having a cross-track and an along-track direction.



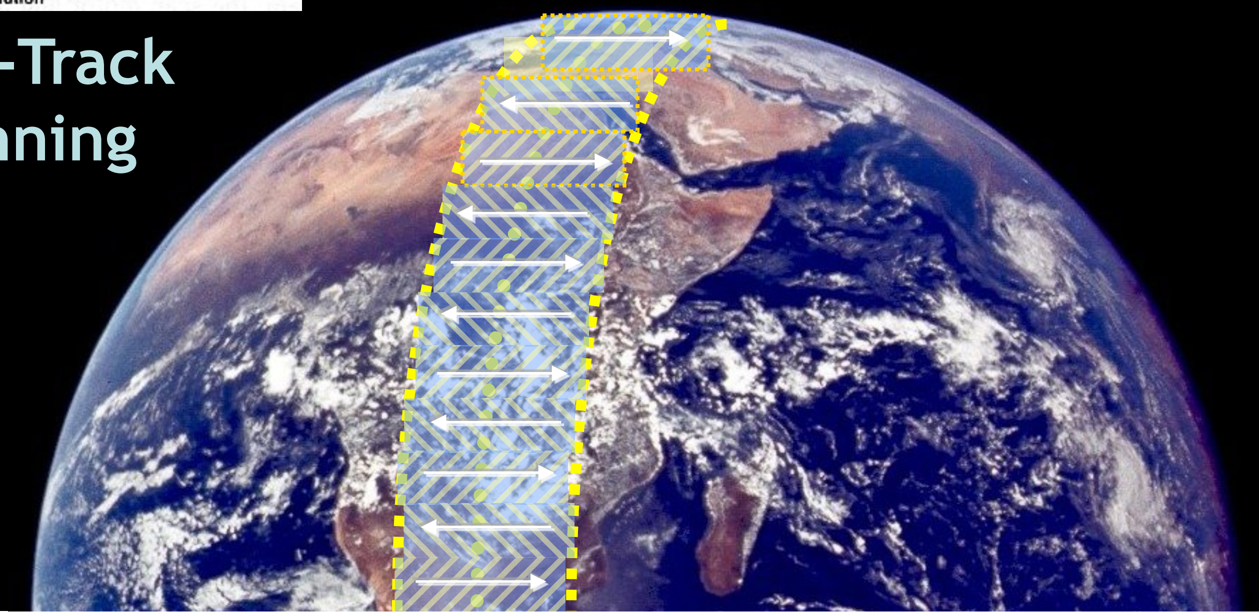


Cross-Track Scanning

Direction of Satellite Motion

"Cross-Track Scanning," Scan mirror swings back and forth.

Sensor observes pixels in sequence across track and along the direction of the satellite's motion.

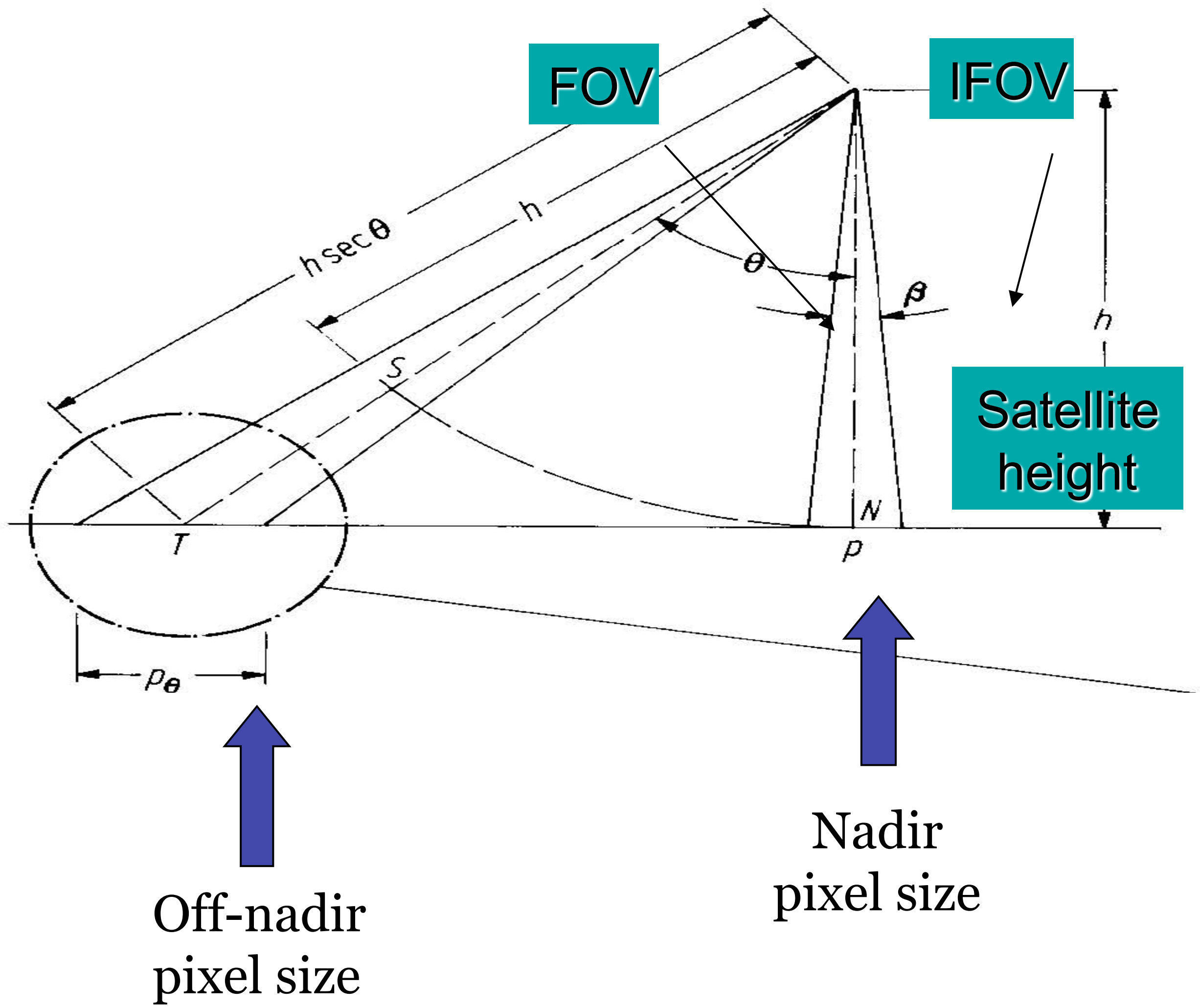


Spatial Resolution

Spatial Resolution

- Spatial Resolution : A simple definition is the pixel size that satellite images cover.

- Satellite images are organized in rows and column called raster imagery and each pixel has a certain spatial resolution.



Spatial Resolution of NASA Satellite Data Products

- **High Spatial resolution**
  250x250m; 500x500 m; 1x1 km; 0.05x0.05 degrees
  Example: MODIS True Color Imagery (RGBs)

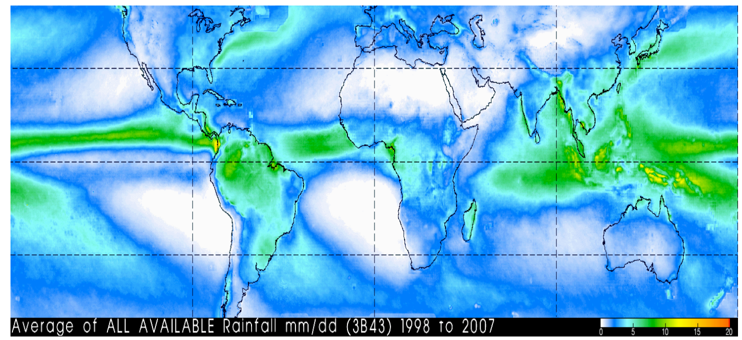
- **Moderate Spatial Resolution**
  0.25x0.25 degrees
  Example: TRMM precipitation products.

- **Low Spatial Resolution (Level 3)**
  Primarily at 1 x 1 degree - derived from each data set's native resolution product
  Example: AIRS surface air temperature

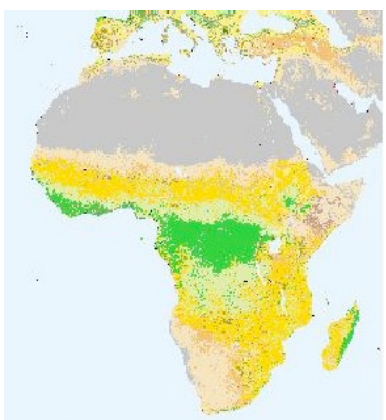
NASA Satellites Measurements with Different Spatial Resolutions

Landsat Image of Philadelphia
Spatial resolution: 30 m

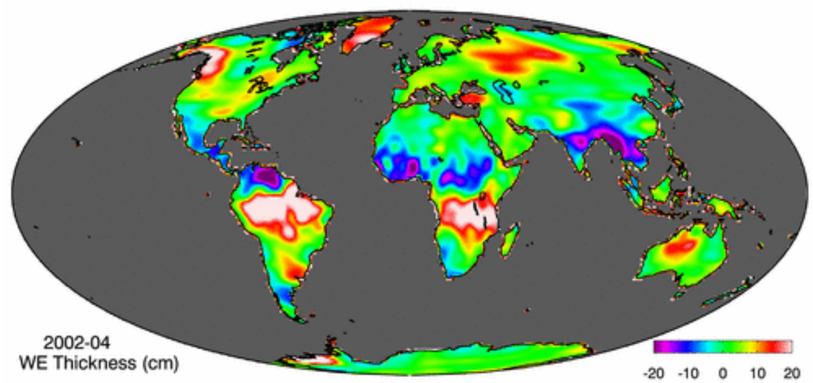
Rain Rate from TRMM
Spatial resolution: 25 km²



Land Cover from Terra/MODIS:
Spatial resolution: 1 km²
(From: http://gislab.jhsph.edu/)



Terrestrial Water Storage Variations from GRACE: Spatial resolution: 150,000 km² or coarser (Courtesy: Matt Rodell, NASA-GSFC)



Temporal Resolution of Remote Sensing Data

The frequency at which data are obtained is determined by:

- Type and height of orbit
- Size of measurement swath

Temporal resolution of Polar Orbiting Satellites Example: Terra, Aqua

- Observations available only **at the time of the satellite overpass.**
- IR based observations available 2X a day (AIRS)
- Visible observations available 1X a day
- Polar regions may have several observations per day.

Temporal resolution of nonpolar satellites
Example: TRMM

- Observations available only **<u>at the time of the satellite overpass.</u>**
- Observations available less than once a day

Note: derived products available at 3-hourly

Remote Sensing - Resolutions

Spectral resolution – The number and range of spectral bands.

More bands = More information

Radiometric resolution – The bandwidth of the individual spectral bands. Important for avoiding or taking advantage of "atmospheric windows"

Satellite data levels of processing and formats

Levels of Data Processing and Spatial Resolution

- **Level 1 and Level 2** data products have the highest spatial and temporal resolution

- **Level 3 products** are derived products with equal or lower spatial and temporal resolution than Level 2 products. Available hourly, daily and for some products also monthly

Levels of Data Processing

Level 1 Products

Orbital data

Used to produce

Level 2 Products

Orbital data

Used to produce

Level 3 Products

Global composites of level 2 products

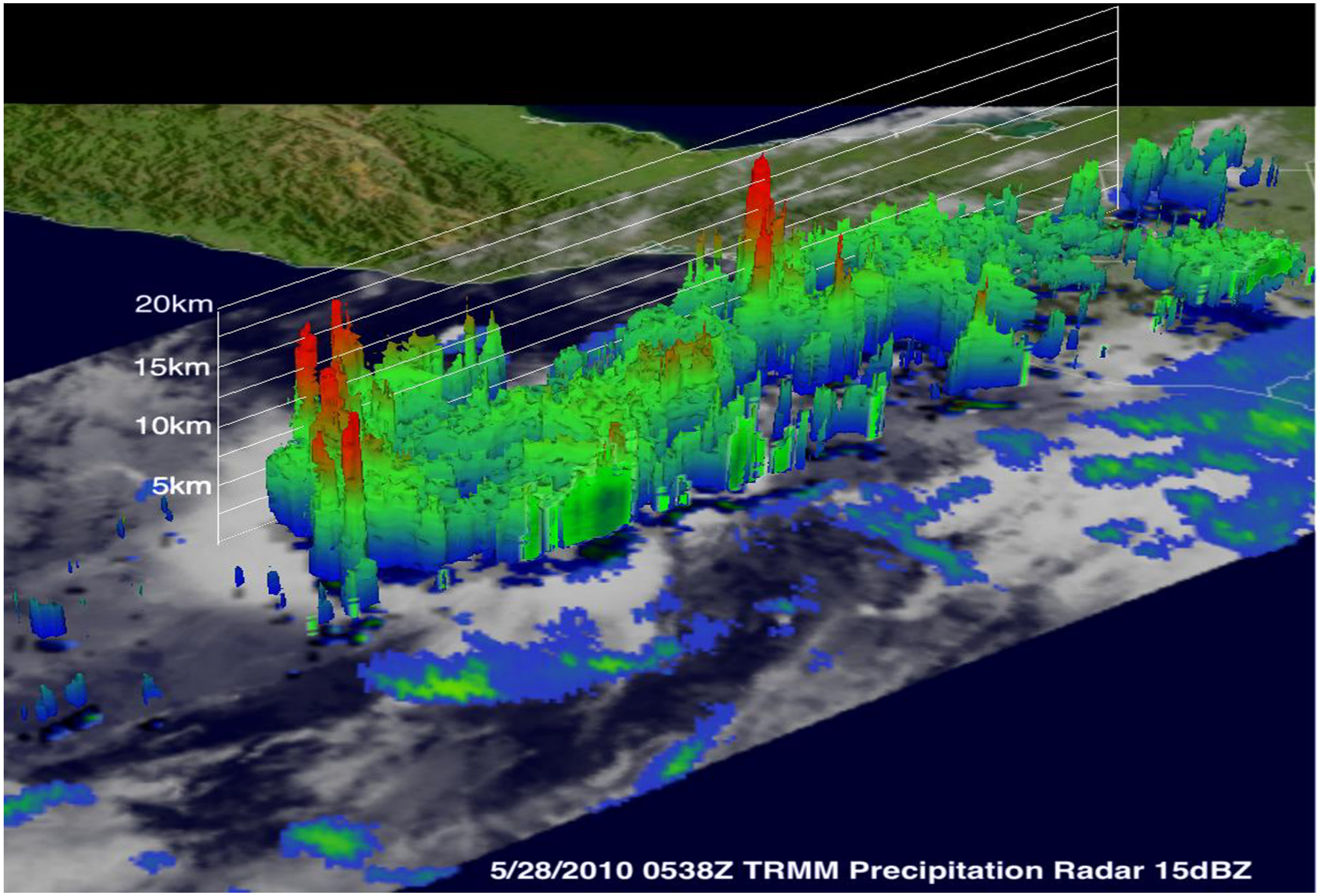
More User Control

Less User Control

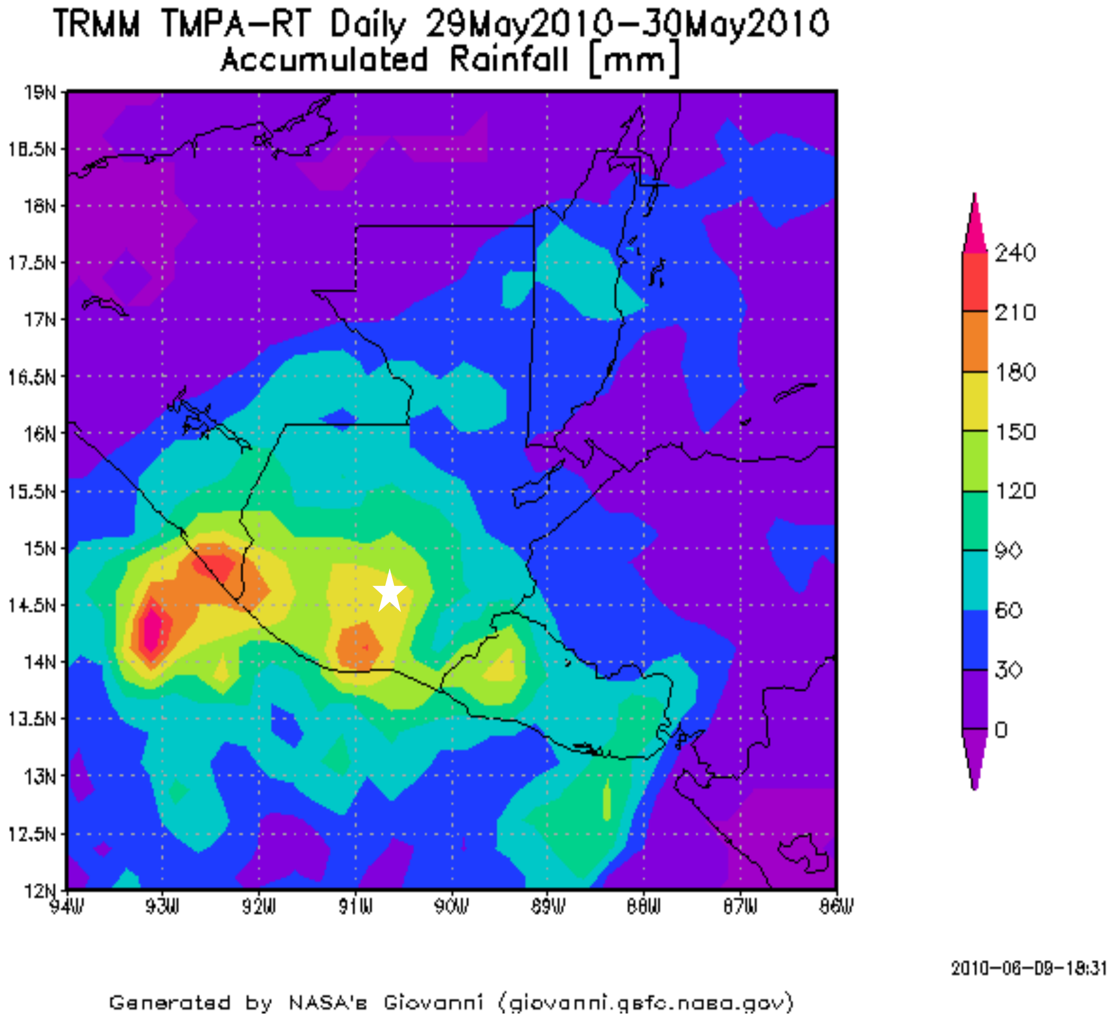
Harder to Use

Easier to Use

Level 2 Example: Guatemala Precipitation Radar from TRMM (4x4 km)



Level 3 Example: TRMM Accumulated Rainfall



0.25x0.25 degree TRMM

Accumulated Rainfall over Guatemala

Remote Sensing Products: Limitations

- There are multiple sources of the same products, with varying spatial/temporal resolutions and accuracies

- There are many assumptions and approximations in going from raw data to specific quantity such as rain amount or

- Data quality can range from excellent to poor depending on:
  - Instrument capabilities
  - Instrument calibration and performance
  - The algorithms used to interpret the data

Data Formats

- **Text/ASCII**

  pros: easy to read and examine the data right away (can read with used tools such as excel and GIS software)

  cons: large data files

- **Binary – HDF, NetCDF**

  pros: takes less space, more information (metadata,SDS)

  cons: need specific tools or code to read the data

- **KML or KMZ (zipped KML)**

  pros - easy 2D and 3D visualization of the data

  through free tools such as Google Earth. Data are very low volume

- **Shapefiles/Geotiff**: GIS Applications. May or may not work with open source

HDF Data Formats

HDF is the standard format for most NASA data

HDF files contain both data and metadata

SDS - Each parameter within an HDF file is referred to as an SDS (Scientific Data Set)

An SDS must be referenced precisely according to name when analyzing the data with your own computer code.